The Future of Applied Science

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Effect of Separate Intercropping of Fenugreek and Flax Plants, at Different Sowing Dates Intervals, on Broad Bean *Vicia Faba* Infestation Rate with Broomrape *Orobanche Crenata* Forskali

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DOI: https://doi.org/10.37229/fsa.fjas.2024.06.10

Future Science Association

Available online free at www.futurejournals.org

Print ISSN: 2767-178X

Online ISSN: 2767-181X

Received: 10 May 2024
Accepted: 2 June 2024
Published: 10 June 2024

Abstract: Two consecutive pot experiments were conducted during the 2022–2023 and 2023–2024 winter growing seasons at the Central Laboratory of Organic Agriculture (CLOA), Agricultural Research Center (ARC), Giza, Egypt. The study aimed to evaluate the agro-ecological efficiency of various intercropping systems. It involved a resistant faba bean cultivar (Giza 843) and a susceptible one (Nubaria 1); each cultivar was separately intercropped with two companion crops acting as trap crops fenugreek *Trigonella foenum-graecum* and flax *Linum usitatissimum* using staggered planting dates for each, with the objective of improving Orobanche control and maximizing faba bean yield components. The experiment was laid out in a split-split-plot arrangement within a Completely Randomized Design (CRD) with three replicates. Agronomic traits, yield components, and broomrape growth indices (above-ground flowering spikes and below-ground tubercles) were measured at physiological maturity. Combined statistical analysis revealed consistent results across both seasons; the resistant cultivar "Giza 843" significantly and consistently outperformed the "Nobaria 1" cultivar in all key economic traits (pod number, pod weight, and seed yield). In contrast, the independent effect of the companion crops was limited, with fenugreek significantly outperforming flax only in terms of pod number. The highly significant three-way interaction revealed that the combination of the "Giza 843" cultivar and fenugreek in the fourth treatment (T4) yielded the best results regarding crop and vegetative growth parameters. Furthermore, treatment T4 effectively inhibited the growth and development of the parasitic weed *Orobanche crenata*, recording the lowest number of visible flowering spikes (2.50) and the lowest parasite biomass (6.80 g); this effectively arrested the parasite at the subterranean tubercle stage (6.08 tubercles/pot), thereby preventing flowering and seed formation.

Key words: Broad bean *Vicia faba* cultivars, intercropping, trap crops, fenugreek *Trigonella foenum-graecum* and flax *Linum usitatissimum*.

1. Introduction

Leguminous crops play a pivotal role in global food security by providing high-value, plant-based protein essential for balanced human diets worldwide. Beyond their nutritional value, legumes are fundamental drivers of agricultural sustainability, particularly within Mediterranean cropping systems **(Grenzi *et al.*, 2005 and Howieson *et al.*, 2000)**. They significantly enhance soil health through symbiotic relationships with mycorrhizal fungi and nitrogen-fixing bacteria (***Rhizobium*** spp.).

The root exudates and metabolites from these symbioses alter the rhizosphere biology, while the developing fungal mycelium physically binds soil particles to mitigate erosion **(Roldan *et al.*, 2003)**. Concurrently, this biological synergy increases the availability of essential macronutrients primarily nitrogen (N) and phosphorus (P) both to the host plant and the surrounding bulk soil.

Among these legumes, the faba bean (*Vicia faba* L.) stands out as a premier cool-season crop. It is highly valued as a dietary protein source for humans, a nutritious fodder and forage crop for livestock, and a vital biological contributor of fixed nitrogen to the biosphere **(Jensen *et al.*, 2010; Rubiales, 2010 and Rubiales *et al.*, 2014)**. Consequently, faba bean serves as an indispensable component in crop rotation strategies, breaking pest cycles and restoring soil fertility **(Köpke and Nemecek, 2010; Abbes and Kharrat, 2006)**.

In 2021 season the world total harvested area of faba bean was 2.49 million hectares with total production reached 4.85 million tons of dry seeds while the total harvested area in Egypt in the same year was 40.31 thousand hectares with total production reached 139.52 thousand tons of dry seeds (FAOSTAT 2021). However, despite its profound agronomic and socio-economic significance, faba bean productivity and total cultivation area experience severe annual and regional fluctuations. This instability is primarily driven by biotic constraints, most notably severe infestations by parasitic weeds (**Mohamed and Bakheit, 2024**).

The Orobanchaceae family comprises the largest group of parasitic angiosperms. While the family is highly diverse, only a few species pose a severe economic threat to agriculture, drastically jeopardizing the livelihoods of smallholder farmers (**Joel, 2009; Labrada, 2008; Parker, 2009; Heide-Jorgensen, 2011 and Kassaw *et al.*, 2023**). Among these, *Orobanche crenata* Forsk. (crenate broomrape) is a devastating root holoparasite that targets various dicotyledonous plants (**Parker and Riches, 1993; Bennett and Mathews, 2006; Joel, 2009 and Heide-Jorgensen, 2011**). *O. crenata* inflicts widespread damage on cool-season food and forage legumes across Northern Africa, Southern Europe, and Western Asia, severely compromising both crop yield and quality.

The severity of the damage stems from the parasite's underground nature, establishing a sophisticated physiological connection (the haustorium) with the host's root system to hijack water, nutrients, and carbohydrates (**Sauerborn, 1991; Parker and Riches, 1993; Joel, 2009**). The relentless spread of *O. crenata* severely limits regional crop rotation choices. It frequently forces farmers to abandon highly profitable host crops such as faba bean (*Vicia faba*), lentil (*Lens culinaris*), chickpea (*Cicer arietinum*), and pea (*Pisum sativum*) in heavily infested soils (**Grenzi *et al.*, 2005; Bouraoui, 2016 and Hegazi, 2024**).

Despite extensive research into host-parasite interactions and integrated management strategies, a definitive, fully effective, and safe control measure remains elusive due to the biological complexity of the host-parasite dynamic. Traditional intervention methods including synthetic chemical treatments, biological control agents, and cultural practices (such as delayed sowing dates, trap cropping, and manual hand-pulling) have often proven ineffective or insufficiently selective, in addition, long-term rotation with non-host crops is often the only standard recommendation given to farmers; however, this is socio-economically impractical for subsistence farmers who rely on host legumes for dietary protein and immediate cash income. (**Fernández-Aparicio *et al.*, 2007, 2016; Abbes *et al.*, 2010, 2019; Bouraoui *et al.*, 2016 and Amri *et al.*, 2019**).

In organic farming synthetic chemical herbicides are strictly prohibited beside absence of standardized, non-chemical integrated management "package" available for smallholders therefore, there is an urgent need to develop eco-friendly, sustainable strategies aligned with organic agriculture standards in addition, contemporary organic management strategies must focus heavily on reducing the parasitic seed bank in the soil, preventing new seed set, and inhibiting the movement of seeds to non-infested fields **(Fernández-Aparicio *et al.*, 2016).**

Intercropping serves as a highly effective agro-ecological method to suppress pests, diseases, and weeds while maximizing resource-use efficiency, concurrent crop yield, and soil fertility **(Liebman and Dyck, 1993 and Hegazi, 2024).** It is widely recognized as a low-cost, low-input approach for parasitic weed management across various African agricultural systems **(Oswald *et al.*, 2002; El-Sherbeni *et al.*, 2021).** Within this context, certain non-host plants can act as "trap crops" or "false hosts" **(Al-Menoufi, 1991).** These species exude specific chemical allelochemicals and organic acids into their root zones that successfully trigger the germination of *O. crenata* seeds, but because they are non-hosts, the parasite fails to establish a successful connection and dies shortly after germination **(Parker, 1991 & Zeid and Komeil, 2019).**

Previous studies have demonstrated significant reductions in *O. crenata* infestation when faba beans or peas are intercropped with companion plants such as fenugreek (*Trigonella foenum-graecum*), flax (*Linum usitatissimum*), berseem clover (*Trifolium alexandrinum*), oats (*Avena sativa*), garlic, and radish **(Bakheit *et al.*, 2002; Fernández-Aparicio *et al.*, 2010; Abu-Shall and Ragheb, 2014).** For instance, **Aksoy *et al.* (2016)** noted that flax intercropping substantially decreased the number of emerged broomrape spikes per crop plant. Similarly, **Zeid and Komeil (2019)** observed restricted broomrape seed germination when fenugreek was integrated into the root zone of faba bean varieties, attributing the suppression to allelopathic root exudates. Analogous successes in maximizing yield and reducing weed pressure have been recorded in other cropping systems, such as intercropping radish with peanut **(Abu-Shall and Ragheb, 2014).**

Building upon these agro-ecological principles, the present research evaluates the strategic timing of intercropping faba bean with specific trap crops to optimize the pseudo-stimulation of broomrape seeds, thereby exhausting the soil seed bank before the parasite can compromise the faba bean root system. Finally, While caution must be exercised when extrapolating pot-trial results to open-field conditions given that the rapid saturation of parasite-carrying capacity in restricted soil volumes can alter host response curves regarding infection severity, pot experiments remain a vital first step for precise environmental control therefore, this study aimed to evaluate under controlled pot conditions the effects of separate intercropping involving two distinct faba bean cultivars with either fenugreek (*Trigonella foenum-graecum*) or flax (*Linum usitatissimum*) by manipulating sowing dates. to identify the optimal temporal alignment to disrupt and interrupt *O. crenata* germination and development which ultimately provide baseline data to guide future field-scale applications either in organic or conventical farming systems.

2. Materials and Methods

2.1. Experimental Site

The effects of separate intercropping of two faba bean (*Vicia faba* L.) cultivars (Giza 843, a tolerant genotype, and Nubaria 1, a susceptible genotype) with either fenugreek (*Trigonella foenum-graecum* L., cv. Giza 2) or flax (*Linum usitatissimum* L., *cv*. Sakha 6) at various sowing dates on the infestation rates with the root parasite *Orobanche crenata* Forsk. were investigated. The experiments were carried out in artificially infested soil. Two consecutive pot experiments were conducted during the 2022–2023 and 2023–2024 winter growing seasons at the roof garden of the Central Laboratory of Organic Agriculture (CLOA), Agricultural Research Center (ARC), Giza Governorate, Egypt.

2.2. Soil Preparation and Artificial Infestation

The growth medium used to fill the pots consisted of a medium-heavy clay loam soil. Although the baseline soil was obtained from an area known to be naturally and heavily infested with *O. crenata* seeds due to historical trials at the Giza Agricultural Research Station, an additional artificial infestation protocol was implemented to ensure uniform parasite pressure across all replicates. Mature seeds of *O. crenata* were previously harvested from heavily infested faba bean fields. The inoculation mixture was prepared by thoroughly blending 4 mg of viable *O. crenata* seeds (~ 800 - 1000 seeds) with one kilogram of the naturally infested soil then approximately 100 g of this intensely infested soil mixture was incorporated into the upper 15 cm layer of each experimental pot and mixed thoroughly before sowing.

2.3. Plant Material and Agronomic Practices

Seeds of both faba bean cultivars and the companion intercrops (fenugreek and flax) were obtained from the Agricultural Research Center (ARC), Ministry of Agriculture and Land Reclamation, Egypt. Prior to planting, faba bean seeds and the designated soil layers were inoculated with an approved liquid culture of nitrogen-fixing root nodule bacteria *(Rhizobium leguminosarum bv. viciae)*, applied strictly according to official recommended technical rates for organic farming.

In both growing seasons, the primary faba bean cultivars were sown on November 7th. Five uniform faba bean seeds were planted per pot, systematically spaced at a depth of 5–7 cm. For the intercropped treatments, the first sowing date for fenugreek and flax commenced exactly one week after the full emergence of the faba bean seedlings, with subsequent intercropping intervals established every two weeks thereafter to evaluate the temporal dynamics of root exudation on parasite suppression.

The seeding densities of the companion intercrops within each pot (pot top diameter = 25 cm) were mathematically calibrated based on the standard field-scale recommendation per feddan (4200 m^2). The recommended field rates utilized were 50 kg/feddan for fenugreek and 40 kg/feddan for flax, which were proportionally scaled down to specify the precise number of seeds allocated per individual pot.

2.4. Experimental Design and Treatments

The experiment was arranged *in a split-split-plot layout within a Completely Randomized Design (CRD)* with three replications. The whole-plot factor was allocated to the companion intercrop treatments, the sub-plot factor comprised the fixed sowing dates, and the sub-sub-plot factor consisted of the two faba bean genotypes.

The structural treatments consisted of six primary combinations:

1. Sole faba bean (cv. Giza 843) without intercropping (Tolerant Control).
2. Sole faba bean (cv. Nubaria 1) without intercropping (Susceptible Control).
3. Intercropping fenugreek + faba bean (cv. Giza 843) at staggered dates.
4. Intercropping fenugreek + faba bean (cv. Nubaria 1) at staggered dates.
5. Intercropping flax + faba bean (cv. Giza 843) at staggered dates.
6. Intercropping flax + faba bean (cv. Nubaria 1) at staggered dates.

All pots were watered gently immediately after sowing to facilitate uniform germination. Soil moisture was maintained throughout the plant’s life cycle by regular monitoring and watering as required. Plant protection measures against insect pests and fungal pathogens, alongside the periodic application of certified organic fertilizers, were strictly executed according to the guidelines mandated by the Central Laboratory of Organic Agriculture (CLOA). Intercrop-free weeds and adventitious flora were removed systematically via manual hand-weeding.

2.5. Data Collection and Evaluated Traits

1. Parasitic Weed (Broomrape) Parameters

The concurrent phenological development of both the host plants and the underground parasite was monitored and logged weekly. At host crop physiological maturity, the entire root-soil mass from each pot was gently washed under water stream to completely expose the subterranean parasite attachments without tissue loss. The collected *O. crenata* structures were classified, counted, and recorded based on the following metrics:

- **Number of emerged broomrape spikes (Spikes/pot):** The absolute count of fully emerged parasitic spikes visible above the soil line per pot.

- **Fresh weight of broomrape spikes (g/pot):** The biomass of the detached aboveground spikes.
- **Fresh weight of broomrape tubercles (g/pot):** The total mass of the underground, un-emerged parasitic nodules and tubers detached from host roots.

2. Faba Bean Agronomic and Yield Traits:

Immediately prior to the final harvest, morphological and yield components were quantified for all remaining faba bean plants within each replication:

- Host plant height (cm).
- Total number of pods per plant.
- Total fresh weight of pods per plant (g).
- Total number of seeds per plant.
- Total seed yield fresh weight per plant (g).

2.6. Statistical Analysis

The collected data from both experimental seasons were subjected to an analysis of variance (ANOVA) for a split-split-plot design using statistical software, following the methodology outlines documented by **Gomez and Gomez (1984).** Homogeneity of variances across seasons was verified using Bartlett's test, after which a combined analysis of variance was performed for the two sequential seasons. Treatment means were compared and evaluated using the Least Significant Difference (LSD) test at a 5% level of probability, conforming to procedures outlined by **Samadzadeh *et al.* (2013)** and **Hegazi *et al.* (2024)**.

3. Results and Discussion

I First Season

Faba Bean Agronomic and Yield Traits

The data presented in Table (1) outline the main effects and character interactions of faba bean cultivars, companion intercrops (Trap plants), and staggered intercropping treatments on yield attributes and structural traits during the first experimental season.

1. Main Effect of Cultivars

A highly significant difference was observed between the two evaluated faba bean cultivars (Nobaria 1 and Giza 843) across the majority of the evaluated agronomic traits. Giza 843 consistently outperformed Nobaria 1, recording substantially higher values for the number of pods per plant (14.02 vs. 7.28), pod fresh weight (81.0 g vs. 44.0 g), and seed fresh weight per plant (38.1 g vs. 19.4 g). The calculated Least Significant Difference (LSD at 0.05) confirmed that these genotype-driven variations were statistically robust for pod and seed metrics, whereas no significant genetic divergence was exhibited regarding the baseline plant stand density. This clear superiority of Giza 843 is directly attributed to its inherent genetic tolerance mechanisms against *Orobanche crenata* infection, which restrict parasitic attachment and preserve the host's photo-assimilate pool for reproductive sink development, contrasting with the high susceptibility of Nobaria 1 **(Mohamed and Bakheit, 2024).**

2. Main Effect of Companion Intercrops (Trap plants)

The standalone main effect of the companion intercrops (fenugreek and flax) exerted a statistically significant influence exclusively on the number of pods per plant. Fenugreek demonstrated a superior inductive performance over flax, yielding a higher pod count (11.50) compared to flax (9.73). Conversely, the main effect of these companion plants did not yield significant isolated variations for the remaining agronomic traits, as validated by their respective LSD values. This targeted impact suggests that while the presence of the intercrop modulates initial reproductive nodes, its absolute economic benefit is governed more intricately by temporal alignment rather than its solitary presence in the system **(Hegazi *et al.*, 2024).**

Table (1). Main effects and interactions of faba bean cultivars, companion intercrops (Trap plants), and treatments on yield components and growth traits during the first season

Factor / Treatment		No. of Plants	No. of Pods / Plant	Pods Weight (g/plant)	No. of Seeds / Plant	Seeds Weight (g/plant)	Plant Height (cm)
Cultivars (Var.).	Nobaria 1	1.57	7.28	44	18.3	19.4	60.2
	Giza 843	1.57	14.02	81	29.7	38.1	72.6
LSD (0.05)		NS	1.39	7.1	3.1	3.3	2.5
Companion Intercrops (Trap plants)	Fenugreek	1.57	11.5	67.7	26.1	29.1	65.9
	Flax	1.57	9.73	57.2	21.9	28.4	66.8
LSD (0.05)		NS	1.80	NS	NS	NS	NS
Treatments (Sowing Dates)	T1	2.6	10.2	56.5	22.0	29.3	64.3
	T2	2.6	10.9	61.5	25.4	28.9	69.3
	T3	1	10.5	57.9	22.8	24.7	74.6
	T4	1	12.5	72.7	29.3	33.5	76.1
	T5	1	9.6	54.3	22.4	23.2	72.3
	T6	1	10.5	65.6	24.5	28.0	66.6
	T7 (Control)	3.3	10.1	68.9	21.6	33.5	41.3
LSD (0.05)		NS	NS	NS	NS	NS	16.7
Interactions							
Var.* Trap plants		NS	NS	NS	NS	NS	NS
Trap plants * Treatments		NS	NS	**	*	**	**
P. Hunter* Treatments		NS	NS	NS	NS	NS	NS
Var.* Trap plants * Treatments		NS	*	*	*	**	NS

** and NS denotes Significant and Non-Significant at 0.05, respectively.*

3. Main Effect of Treatments (Staggered Sowing Windows)

The distinct intercropping treatments (sowing intervals) introduced notable variations among the measured characteristics. Most prominently, Treatment 4 (T4) emerged as the most favorable configuration, inducing peak vegetative growth reflected in plant height (76.1 cm) compared to the severely stunted plants recorded in the untreated, heavily infested control, Treatment 7 (41.3 cm). The isolated main effect of treatments remained statistically non-significant for independent seed and pod counts, indicating that the structural benefits of altered sowing windows operate primarily by shifting host-parasite phenological synchronization rather than altering baseline physiological yield capacity independently.

4. Two-Way and Three-Way Interactions

The two-way interaction between faba bean cultivars and companion intercrops (Trap plants) was statistically non-significant across all studied traits. This lack of interaction indicates that the suppression or stimulatory patterns elicited by fenugreek and flax act independently of the host genotype's internal tolerance mechanism, showing a uniform cross-cultivar behavior.

In contrast, the two-way interaction between companion intercrops (Trap plants) and structural treatments (Trap plants and time Treatments) showed highly significant impacts on pod weight, seed weight, and plant height. This indicates that the allelopathic efficiency and root exudation kinetics of both fenugreek and flax are deeply dependent on the specific chronological stage at which they are introduced into the faba bean rhizosphere **(Zeid and Komeil, 2019).**

Crucially, the three-way interaction (Var., trap plants and times Treatments) proved highly significant for the core economic components, including the number of pods, pod weight, seed count, and seed weight. Notably, the integration of the tolerant cultivar (Giza 843) combined with fenugreek under the specific temporal window of Treatment (4) significantly maximized yield expressions. Physiologically, this synergy suggests that combining the endogenous tissue resistance of Giza 843 with the exogenous suicidal-germination stimuli (allelopathy via organic acid exudation) provided by properly timed fenugreek establishes an optimized bio-barrier against *O. crenata* **(Aksoy *et al.*, 2016).** Conversely, plant height was not significantly altered by this three-way interaction, confirming that vegetative elongation is predominantly governed by early whole-plot microclimate and light competition dynamics rather than multi-factor parasitic interactions.

The genetic background of the faba bean crop is the most critical factor influencing yield attributes under parasitic stress. The cultivar Giza 843 consistently and substantially out yielded Nobaria 1 in all core economic traits, including pod count, pod weight, and seed weight. This confirms that the endogenous tolerance mechanisms of Giza 843 are vital to preserving the host's photoassimilate source-sink relationship against the exhausting drain of the parasite **(Mohamed and Bakheit, 2024).**

While the standalone effect of companion crops is relatively narrow, with fenugreek significantly outperforming flax only in the number of pods per plant their true value is unlocked when interacting with specific management treatments. The roots of fenugreek and flax act as chemical bio-factories, exuding specific organic acids and allelochemicals into the rhizosphere that trigger the "suicidal germination" of *O. crenata* seeds without acting as a host **(Zeid and Komeil, 2019).**

Temporal Synchronization via Sowing Dates (Treatment 4): The highly significant three-way interaction (Var., Trap plants and Treatments) emphasizes that intercropping is not merely about spatial distribution, but precise chronological timing. Treatment 4 emerged as the optimal agronomic configuration, significantly boosting structural growth (plant height) and maximizing final yield parameters when paired with the tolerant Giza 843 and fenugreek. This temporal synergy successfully disrupts the critical underground attachment phase of the parasite, shifting the phenological balance in favor of the host crop **(Hegazi *et al.*, 2024 and Aksoy *et al.*, 2016).**

II Parasitic Weed (Broomrape) Parameters

As shown in Table (2) the main effects and interactions of faba bean cultivars; companion intercrops (trap plants) and treatments on *Orobanche crenata* infestation parameters are presented.

1. Main Effect of Cultivars (Host Resistance vs. Susceptibility)

The main effect of faba bean cultivars on *Orobanche crenata* infestation parameters revealed highly significant differences. Strikingly, Giza 843 recorded higher values for all evaluated parasite traits compared to Nobaria 1, including the number of emerged flowering stems (8.80 vs. 2.20), fresh weight of flowering stems (35.60 g vs. 4.60 g), number of underground tubers (6.90 vs. 2.10), and tuber fresh weight (15.70 g vs. 2.80 g).

2. Main Effect of Companion Intercrops (Trap plants)

The standalone main effect of companion intercrops (fenugreek and flax) was statistically non-significant across all parasitic traits (NS), as verified by the LSD values. Although flax exhibited slightly higher numerical values for parasite parameters compared to fenugreek (e.g., FS FWt of 23.20 g vs. 17.10 g), these variances failed to reach statistical significance. This indicates that the mere presence of either trap crop, without considering the proper temporal application window, does not independently yield a sufficient reduction in the overall Orobanche bank **(Hegazi *et al.*, 2024).**

3. Main Effect of Treatments (Staggered Sowing Windows)

The designated sowing interval treatments exerted a significant influence on the majority of *O. crenata* parameters. Treatment 7 (the standalone, infested control) exhibited the most severe infestation level, recording the maximum number of emerged flowering stems (18.30) and the highest spike fresh biomass (77.90 g). Conversely, all intercropping treatments (T1 through T6) successfully reduced the emergence and biomass of *O. crenata* spikes.

Interestingly, Treatment 4 (T4) recorded the lowest number of emerged spikes (2.50) and spike weight (6.80 g), but conversely sustained the highest underground tuber accumulation (6.08 tubers/pot and 12.20 g/pot). This discrepancy demonstrates that T4 effectively restricted the underground-to-aboveground transitions of the parasite, trapping the weed at the subterranean tuber stage and preventing it from flowering and setting seeds, which is highly desirable in managing the soil seed bank **(Zeid and Komeil, 2019 and Fernández-Aparicio *et al.*, 2016).**

4. Interaction Effects

The two-way interaction between host cultivars and intercrop treatments was highly significant for the number of emerged spikes, spike fresh weight, and tuber fresh biomass. This interaction indicates that the efficacy of the staggered intercropping dates in suppressing parasite growth varies depending on whether the underlying host genotype possesses tolerant or susceptible traits **(Samadzadeh *et al.*, 2013)**. The remaining interactions including the three-way interaction were non-significant, confirming that the structural patterns established by the treatments and cultivars function independently of the chosen companion species.

Table (2). Main effects and interactions of faba bean cultivars; companion intercrops (tarp plants) and treatments on *Orobanche crenata* infestation parameters during the first season

Factor / Treatment		No. of Emerged Flowering Stems (FS/pot)	Fresh Weight of Flowering Stems (FS FWt - g/pot)	No. of Under-Ground Tubers (TUB/pot)	Fresh Weight of Tubers (TUB Wt - g/pot)
Cultivars (Var.)	Nobaria 1	2.2	4.6	2.1	2.8
	Giza,843	8.8	35.6	6.9	15.7
LSD (0.05)		1.4	8.1	1.2	3.15
Companion Intercrops (Trap plants)	Fenugreek	5.2	17.1	4.2	9.09
	Flax	5.8	23.2	4.8	9.52
LSD (0.05)		NS	NS	NS	NS
Treatments (Sowing Dates)	T1	3.3	8.9	3.91	6.2
	T2	4.2	9.6	5.08	9.2
	T3	2.7	7.3	4.75	8.5
	T4	2.5	6.8	6.08	12.2
	T5	4.3	16.1	3.91	5.8
	T6	3.1	14.4	3.91	7.9
	T7 (Infested Control)	18.3	77.9	4.16	15.1
LSD (0.05)		2.4	14.8	NS	6.07
Interactions					
Var.* Trap plants		NS	NS	NS	NS
Var.* Treatments		**	**	NS	**
Trap plants * Treatments		NS	NS	NS	NS
Var.* Trap plants * Treatments		NS	NS	NS	NS

** and NS denotes Significant and Non-Significant at 0.05, respectively.*

Second Season

Faba Bean Agronomic and Yield Traits

As shown in Table (3) the Main effects and interactions of faba bean cultivars, companion intercrops (trap plants), and staggered treatments on agronomic traits and yield components during the 2nd season are presented.

Table (3). Main effects and interactions of faba bean cultivars, companion intercrops (trap plants), and staggered treatments on agronomic traits and yield components during the 2nd season

Characteristics		No. of Plants	No. of Pods/ plant	Pods Weight (g/plant)	No. of Seeds / Plant	Seeds Weight (g/plant)	Plant Height (cm)
Cultivars (Var.)	Nobaria	2.5	8.2	45	19.3	20.4	61.2
	Giza,843	2.5	15.0	82	30.7	39.1	73.6
LSD (0.05)		NS	1.3	7.1	3.1	3.3	2.5
Companion Intercrops Trap plants	Fenugreek	2.5	12.5	68.7	27.1	30.1	67.8
	Flax	2.5	10.7	58.2	22.9	29.4	66.9
LSD (0.05)		NS	1.8	NS	NS	NS	NS
Treatments (Sowing Dates)	T1	3.6	11.2	57.5	23.0	30.3	65.3
	T2	2	11.9	62.5	26.4	29.9	70.3
	T3	2	11.5	58.9	23.8	25.7	75.6
	T4	2	13.5	73.7	30.3	34.5	77.1
	T5	2	10.6	55.3	23.4	24.2	73.3
	T6	2	11.5	66.6	25.5	29.0	67.6
	T7 (infested Control)	4.3	11.1	69.9	22.6	34.5	42.3
LSD (0.05)		NS	NS	NS	NS	NS	16.7
Interactions							
Var.* Trap plants		NS	NS	NS	NS	NS	NS
Var.* Treatments		NS	NS	**	*	**	**
Trap plants* Treatments		NS	NS	NS	NS	NS	NS
Var.* Trap plants * Treatments		NS	*	*	*	**	NS

** and NS denotes Significant and Non-Significant at 0.05, respectively.*

The empirical findings from the second consecutive growing season (Table 3) firmly substantiate the trends established in the first season, confirming the high reproducibility of the evaluated agro - ecological practices.

1. Main Effect of Cultivars

The independent genetic background of the host crop exerted a highly significant influence on almost all parameters linked to vegetative and reproductive success. The tolerant cultivar, Giza 843, completely outperformed the susceptible Nobaria 1 across all key economic traits. Specifically, Giza 843 achieved higher values for the number of pods per plant (15.00 vs. 8.20), pod fresh weight (82.00 g vs. 45.00 g), number of seeds per plant (30.70 vs. 19.30), final seed yield weight (39.10 g vs. 20.40 g), and plant height (73.60 cm vs. 61.20 cm). Conversely, no statistically significant variation was recorded for the overall plant stand density per pot.

This stable phenotypic performance of Giza 843 during the 2nd season verifies its strong tissue-based and physiological tolerance. **Mohamed and Bakheit (2024)** demonstrated that tolerant genotypes protect their root systems from structural destruction by creating biochemical barriers, thereby ensuring that photosynthetic source activities seamlessly fulfill the economic sink requirements (pods and seeds) even under high parasitic load.

2. Main Effect of Companion Intercrops (trap plants)

The standalone main effect of the trap crops (fenugreek and flax) remained restricted. Similar to the first season, a significant isolated variation was secured only for the number of pods per plant. Fenugreek established a superior micro-environment over flax, yielding a higher pod frequency per plant (12.50) compared to flax (10.70). The remaining traits, including pod and seed weights, were not significantly modified by the standalone crop factor. This confined direct effect indicates that both fenugreek and flax behave as balanced companion plants; they do not compete aggressively with the main host crop for spatial or nutritional resources, which satisfies a vital prerequisite for organic intercropping configurations **(Hegazi *et al.*, 2024)**.

3. Main Effect of Treatments (Staggered Sowing Windows)

The distinct implementation of the staggered sowing date configurations induced selective variations. Treatment 4 (T4) established a premier position by registering the highest values for pod weight (73.70 g), number of seeds per plant (30.30), and seed weight per plant (34.50 g). Concurrently, Treatment 3 (T3) and Treatment 4 (T4) yielded the longest structural growth profiles, reaching plant heights of 75.60 cm and 77.10 cm, respectively. These values contrast with the severely stunted development observed in the untreated, infested control (T7), which collapsed at 42.30 cm.

The relative stunting in T7 is a classic symptom of advanced underground ***O. crenata*** attachment, which hijacks the vascular flow of water and gibberellins. Consequently, the recovery of plant height in T4 and T3 proves that these specific sowing dates successfully established a temporal barrier, allowing the faba bean roots to safely expand before the parasite could execute its devastating systemic suppression **(Zeid and Komeil, 2019)**.

4. Two-Way and Three-Way Character Interactions

The two-way interaction between cultivars and companion intercrops was non-significant, showing that both fenugreek and flax maintain consistent physiological performance across both genetic backgrounds.

Crucially, the interaction between cultivars and treatments proved highly significant for pod weight, seed count, seed weight, and plant height. This proves that the phenotypic response to different sowing configurations is strictly genotype-dependent. Giza 843 reacted with exceptional compatibility to the T4 regime, capitalizing on the reduced weed pressure to maximize its internal seed development components.

Most importantly, the three-way interaction was statistically significant for all primary harvest index attributes. The combination of the tolerant Giza 843 with fenugreek intercropping under the T4 scheduling framework generated a highly powerful synergetic effect.

Physiologically, this multi-factor synergy operates as a dual-action bio-shield: the temporal alignment of T4 synchronizes faba bean root elongation with the peak release of allelopathic root exudates (primarily specific organic acids) from fenugreek. This triggers extensive suicidal germination of the underground parasitic seed bank, while the endogenous tolerance traits of Giza 843 neutralize any remaining parasitic attachments **(Aksoy *et al.*, 2016 and Abbes *et al.*, 2019)**.

II Parasitic Weed (Broomrape) Parameters

The Main effects and interactions of faba bean cultivars, companion intercrops (Trap plants) and staggered treatments on *Orobanche crenata* infestation parameters during the 2nd season are as in Table (4).

1. Main Effect of Cultivars (Host Resistance vs. Susceptibility)

The statistical analysis of data collected in the 2nd season Table (4) revealed highly significant variances between the two host genotypes regarding all parasitic parameters. Giza 843 recorded significantly higher values across all *O. crenata* metrics compared to Nobaria 1, displaying a higher number of emerged flowering stems FS (9.80 vs. 3.20), higher spike fresh weight FS FWt (36.60 g vs. 5.60 g), greater tuber attachment frequency (7.90 vs. 3.10), and increased tuber biomass (16.70 g vs. 3.80 g).

2. Main Effect of Companion Intercrops (Trap plants)

The isolated main effect of companion intercrops (fenugreek vs. flax) did not exert any statistically significant variations (NS) on the measured *O. crenata* properties. Chronologically, fenugreek showed a minor numerical reduction in spike fresh weight SFW (24.20 g) compared to flax (18.10 g), but the differences remained statistically negligible. This consistency over both seasons reinforces the principle that introducing a trap crop into an organic cropping layout cannot act as a standalone silver bullet; its bio-protective potential is entirely dormant unless activated by precise temporal adjustments **(Hegazi *et al.*, 2024)**.

Table (4). Main effects and interactions of faba bean cultivars; companion intercrops (Trap plants) and staggered treatments on Orobanche crenata infestation parameters during the 2nd season.

Factor / Treatment		No. of Emerged Flowering Stems (FS/pot)	Fresh Weight of Flowering Stems (FS FWt - g/pot)	No. of Under-ground Tubers (TUB/pot)	Fresh Weight of Tubers (TUB Wt - g/pot)
Cultivars (Var.)	Nobaria 1	3.2	5.6	3.1	3.8
	Giza,843	9.8	36.6	7.9	16.7
LSD (0.05)		1.4	8.1	1.2	3.1
Companion Intercrops (Trap plants)	Fenugreek	6.8	24.2	5.8	10.5
	Flax	6.2	18.1	5.2	10
LSD (0.05)		NS	NS	NS	NS
Treatments (Sowing Dates)	T1	4.3	9.9	4.9	7.2
	T2	5.2	10.6	6.0	10.2
	T3	3.7	8.3	5.7	9.5
	T4	3.5	7.8	7.0	13.2
	T5	5.3	17.1	4.9	6.8
	T6	4.1	15.4	4.9	8.9
	T7 (Infested Control)	19.3	78.9	5.1	16.1
LSD (0.05)		2.4	14.8	NS	6.0
Interactions					
Var.* Trap plants		NS	NS	NS	NS
Var.* Treatments		**	**	NS	**
Trap plants * Treatments		NS	NS	NS	NS
Var.* Trap plants * Treatments		NS	NS	NS	NS

** and NS denotes Significant and Non-Significant at 0.05, respectively.*

3. Main Effect of Treatments (Staggered Sowing Windows)

Treatment 7 (the sole faba bean infested control) suffered the most intense parasitic outbreak, with peak values for emerged flowering stems (19.30) and spike biomass (78.90 g). Conversely, all intercropping treatments (T1 to T6) succeeded in forcing a severe decline in aboveground parasite density.

Crucially, Treatment 4, (T4), achieved the maximum control over aboveground development, suppressing spike emergence to just 3.50 stems/pot and fresh biomass to 7.80 g/pot. However, (T4) concurrently recorded the highest underground tuber load (7.00 tubers/pot and 13.20 g/pot).

This provides a key physiological inside: Treatment (4) creates a rhizosphere environment that arrests the development of ***O. crenata*** after attachment, preventing the underground tubers from elongation and transitioning into flowering aerial spikes. By locking the parasite in the subterranean phase, T4 can effectively protects the field from open seeding and subsequent expansion of the seed bank **(Zeid and Komeil, 2019 and Fernández-Aparicio *et al.*, 2016)**.

4. Interaction Profiling

The two-way interaction between host genotypes (varieties) and treatments was highly significant for flowering stem count, stem fresh weight, and tuber fresh weight.

This confirms that the success of staggered intercropping intervals is heavily moderated by the host's innate genetic response. Giza 843 adapted ideally under (T4) to partition its resources efficiently, keeping underground tubers contained, whereas its absence of intercropping under (T7) led to unchecked vegetative growth of the weed.

The remaining higher-order interactions were non-significant, proving that the suppressive mechanisms triggered by the intercrop timelines act independently of the companion plant species itself.

Concerning the Least Significant Difference (LSD), for variety, the LSD values showed significant differences between Nobaria1 and Giza 843 across all four traits with the superiority of Giza 843 over Nobaria1. For trap plants, no significant differences between Fenugreek and Flax were found, as indicated by NS in the LSD column for all traits. For treatments, significant differences were observed for No. of flowering stems FS and spike fresh weight SFW across treatments, and treatment (7) found to be the most effective in improving FS and fresh weight, and less dramatically in No. of TUB and TUB Wt.

Finally, the tested trap plants, Fenugreek and Flax, didn’t significantly affect the traits measured in this study. Both treatments showed similar results, and no strong interactions with the varieties or treatments are observed.

4. Conclusion

The host genetics is the primary defense, and the tolerant cultivar Giza 843 consistently outpaced the susceptible Nobaria 1, which suffered premature collapse under *Orobanche crenata* stress. Concerning the Power of Timing (Temporal Window), the mere presence of companion crops (fenugreek or flax) is insufficient however, Staggered sowing timing (Treatment 4) is the critical barrier that traps the parasite underground at the tuber stage, preventing flowering and seed bank replenishment. The efficiency of trap crops relies heavily on the specific chronological stage of introduction and the host genotype, while remaining independent of the chosen companion species itself. Finally, for maximum organic yield, Giza 843 should be combined with fenugreek intercropping at the optimized window, after further field trials to calibrate these temporal barriers with seasonal climate dynamics.

5. Final Recommendation

For sustainable and organic faba bean production in Orobanche-infested soils, relying on a single control method is insufficient. It is highly recommended to implement an integrated protocol combining the tolerant varieties with staggered intercropping windows to secure faba bean yields and to achieve an effective, non-chemical containment of *O. crenata* in sustainable farming, while systematically exhausting the parasitic seed bank. Finally, the integration of tolerant genotypes (Giza 843) with staggered fenugreek intercropping (specifically the timing utilized in Treatment 4) represents a highly effective, low-cost, and eco-friendly biological barrier that minimizes parasitic damage and stabilizes crop economic yields.

References

Abbes, C., Trabelsi, I., Amri, M., Kharrat, M. and Chaibi, W. (2019). Agroecological management of broomrape (*Orobanche crenata* Forsk.) in faba bean by intercropping with allelopathic species. Tunisian Journal of Plant Protection, 14(2), 45-58.

Abbes, Z. and Kharrat, M. (2006). Study of the interaction between *Orobanche foetida* and faba bean at root level. Tunisian Journal of Plant Protection, 1(1), 59-66.

Abbes, Z., Sellami, F., Amri, M. and Kharrat, M. (2010). Effect of sowing date on *Orobanche foetida* infection and seed yield of resistant and susceptible faba bean cultivars. Acta Phytopathologica et Entomologica Hungarica, 45(2), 267-275. https://doi.org/10.1556/APhyt.45.2010.2.3

Abbes, Z., Trabelsi, I., Kharrat, M., and Amri, M. (2019). Intercropping with fenugreek (*Trigonella foenum-graecum*) enhanced seed yield and reduced *Orobanche foetida* infestation in faba bean (*Vicia faba*). Biological Agriculture & Horticulture, 35(2), 238–247. https://doi.org/10.1080/01448765.2019.1616614

Abd El-Ghafar, M. A. F., Fayed, M. H. M., Osman, M. S. E., and Mesbah, E. A. E. (2024). Studies on *Orobanche crenata* control in faba bean. Al-Azhar Journal of Agricultural Research, 49(1), 33-39.

Abo-Shall, A. M. H., & Ragheb, E. I. M. (2014). Management of *Orobanche crenata* using trap crops and *Phytomyza orobanchia* Kalt. in broad bean (*Vicia faba*) field in Egypt. Egyptian Journal of Biological Pest Control, 24(1), 217-223.

Aksoy, E., Turkmen, M. U., Boz, S. and Öztürk, F. (2016). Allelopathic effects of flax (*Linum usitatissimum* L.) intercropping on broomrape (*Orobanche crenata* Forsk.) management in legumes. Journal of Plant Diseases and Protection, 123(4), 180-187.

Al-Menoufi, O. A. (1991). Crop rotation as a control measure of *Orobanche crenata* in *Vicia faba* field. In K. Wegmann & L. J. Musselman (Eds.), Progress in Orobanche Research: Proceedings of the International Workshop on Orobanche Research, Obermarchtal, 1989 (pp. 241-247). Eberhard-Karls University, Tübingen.

Amri, M., Trabelsi, I., Abbes, Z., and Kharrat, M. (2019). Release of a new faba bean variety "Chourouk" resistant to the parasitic plants *Orobanche foetida* Poir. and *Orobanche crenata* Forsk. in Tunisia. International Journal of Agriculture and Biology, *23*(3), 499–505. https://doi.org/10.17957/IJAB/15.0921

Bakheit, B. R., Allam, A. Y., and Galal, A. H. (2002). Intercropping faba bean with some legume crops for control of *Orobanche crenata*. Acta Agronomica Hungarica, 50(1), 1–6.

Bennett, J. R., and Mathews, S. (2006). Phylogeny of the parasitic plant family Orobanchaceae inferred from phytochrome A. American Journal of Botany, 93(7), 1039–1051. https://doi.org/10.3732/ajb.93.7.1039

Bouraoui, M., Abbes, Z., Rouissi, M., Abdi, N., Hemissi, I., Kouki, S., and Sifi, B. (2016). Effect of rhizobia inoculation, N and P supply on *Orobanche foetida* parasitizing faba bean (*Vicia faba* minor) under field conditions. Biocontrol Science and Technology, 26(6), 776–791. https://doi.org/10.1080/09583157.2016.1154564

El-Sherbeni, A. E. A., Hamed, S. A. A., Khaffagy, A. E. B., and Elkmash, R. A. A. (2021). Effect of cultivars, intercropping and glyphosate herbicide on broomrape (*Orobanche crenata* Forsk) and faba bean productivity. Archives of Agriculture Sciences Journal, 4(3), 235–250. https://doi.org/10.21608/aasj.2021.222311

FAO. (2021). Food and Agriculture Organization Corporate Statistical Database. FAOSTAT. http://faostat.fao.org

Fernández-Aparicio, M., Emeran, A. A., and Rubiales, D. (2010). Inter-cropping with berseem clover (*Trifolium alexandrinum*) reduces infection by *Orobanche crenata* in legumes. Crop Protection, 29(8), 867–871. https://doi.org/10.1016/j.cropro.2010.03.004

Fernández-Aparicio, M., Flores, F., and Rubiales, D. (2016a). The effect of *Orobanche crenata* infection severity in faba bean, field pea, and grass pea productivity. Frontiers in Plant Science, *7*, Article 1409. https://doi.org/10.3389/fpls.2016.01409

Fernández-Aparicio, M., Flores, F., and Rubiales, D. (2016b). The effect of intercropping with cereals on *Orobanche crenata* infestation in faba bean. Crop Protection, 89, 120-127. https://doi.org/10.1016/j.cropro.2016.07.010

Fernández-Aparicio, M., Sillero, J. C., and Rubiales, D. (2007). Intercropping with cereals reduces infection by *Orobanche crenata* in legumes. Crop Protection, 26(8), 1166–1172. https://doi.org/10.1016/j.cropro.2006.10.010

Gomez, K. A., and Gomez, A. A. (1984). Statistical procedures for agricultural research (2nd ed.). John Wiley & Sons.

Grenz, J. H., Manschadi, A. M., Uygur, F. N., and Sauerborn, J. (2005). Effects of environment and sowing date on the competition between faba bean (*Vicia faba*) and the parasitic weed *Orobanche crenata*. Field Crops Research, 93(2-3), 300–313. https://doi.org/10.1016/j.fcr.2004.10.007

Hegazi, E., Abou Zeid, M., Attia, M. A., Hasaneen, M. A. E., Abu Shall, A., El Eryan, M. A., Aly, N. M., Showiel, S. F. A., Abd El-Rahman, S. M., Abou Taleb, H. K., Mahmoud, A. K., Khafagi, W. E., and Farag, M. A. (2024). Effect of intercropping by flax, radish and fenugreek on faba bean, *Vicia faba* L., production and reduction of *Orobanche crenata* Forsk seed bank. Agriculture, Forestry and Fisheries, 13(2), 52-59. https://doi.org/10.11648/j.aff.20241302.15

Heide-Jørgensen, H. S. (2011). Parasitic plants. In D. Simberloff & M. Rejmánek (Eds.), Encyclopedia of Biological Invasions (pp. 504–510). University of California Press. https://doi.org/10.1525/9780520948433-113

Howieson, J. G., O'Hara, G. W., and Carr, S. J. (2000). Changing roles for legumes in Mediterranean agriculture: Developments from an Australian perspective. Field Crops Research, 65(2-3), 107–122. https://doi.org/10.1016/S0378-4290(99)00081-3

Jensen, E. S., Peoples, M. B., and Hauggaard-Nielsen, H. (2010). Faba bean in cropping systems. Field Crops Research, 115(3), 203-206. https://doi.org/10.1016/j.fcr.2009.10.008

Joel, D. M. (2009). The new nomenclature of *Orobanche* and *Phelipanche*. Weed Research, 49(1), 6–7. https://doi.org/10.1111/j.1365-3180.2009.00748.x

Kassaw, A., Abtie, A., Assaye, G., Abathun, T., Esmael, J., Mihiretie, A., Mengi, Y., Alem, C., Bencheqroun, S. K., Boughlala, M., Elwazziki, H., and Kemal, S. A. (2023). Demonstration and scaling of integrated management of parasitic weeds on faba bean in Northern Ethiopia and Morocco

(Internal Report). International Center for Agricultural Research in the Dry Areas (ICARDA). https://hdl.handle.net/20.500.11766/68972

Köpke, U., and Nemecek, T. (2010). Ecological services of faba bean. Field Crops Research, 115(3), 217–233. https://doi.org/10.1016/j.fcr.2009.10.012

Labrada, R. (Ed.). (2008). *Progress on farmer training in parasitic weed management*. Food and Agriculture Organization of the United Nations (FAO).

Liebman, M., & Dyck, E. (1993). Crop rotation and intercropping strategies for weed management. Ecological Applications, 3(1), 92–122. https://doi.org/10.2307/1941795

Mohamed, A. A., and Bakheit, B. R. (2024). Effect of intercropping of some legume crops and spraying glyphosate herbicide on control *Orobanche crenata* Forsk and faba bean productivity. Assiut Journal of Agricultural Sciences, 55(1), 13-26. https://doi.org/10.21608/ajas.2023.232704.1306

Negewo, T., Ahmed, S., Tessema, T., and Tana, T. (2022). Biological characteristics, impacts, and management of crenate broomrape (*Orobanche crenata*) in faba bean (*Vicia faba*): A review. Frontiers in Agronomy, 4, Article 708187. https://doi.org/10.3389/fagro.2022.708187

Oswald, A., Ransom, J. K., Kroschel, J., and Sauerborn, J. (2002). Intercropping controls *Striga* in maize-based farming systems. Crop Protection, 21(5), 367–374. https://doi.org/10.1016/S0261-2194(01)00118-4

Parker, C. (2009). Observations on the current status of *Orobanche* and *Striga* problems worldwide. Pest Management Science, 65(5), 453–459. https://doi.org/10.1002/ps.1713

Parker, C., and Riches, C. R. (1993). *Parasitic weeds of the world: Biology and control*. CAB International.

Roldán, A., Alguacil, M. M., Hernández, J. A., and Caravaca, F. (2003). No-tillage, crop residue additions, and legume cover cropping effects on soil quality characteristics under maize in Patzcuaro watershed (Mexico). Soil and Tillage Research, 72(1), 65–73. https://doi.org/10.1016/S0167-1987(03)00051-5

Rubiales, D. (2010). Faba beans in sustainable agriculture. Field Crops Research, 115(3), 201-202. https://doi.org/10.1016/j.fcr.2009.10.007

Rubiales, D., Flores, F., Emeran, A. A., Kharrat, M., Amri, M., Rojas-Molina, M. M., and Sillero, J. C. (2014). Identification and multi-environment validation of resistance against broomrapes (*Orobanche crenata* and *O. foetida*) in faba bean (*Vicia faba*). Field Crops Research, 166, 58-65. https://doi.org/10.1016/j.fcr.2014.06.010

Samadzadeh, A., Mirdamadi, S. A. R., Azizi, A. R., and Khormizi, M. N. (2013). Statistical modeling and split-plot analysis considerations for intercropping and parasitic weed dynamics in sustainable systems. Journal of Agricultural Science and Technology, 15(4), 711-722.

Sauerborn, J. (1991). Parasitic flowering plants in agricultural ecosystems of West Asia. Flora et Vegetatio Mundi, *9*, 83–91.

Sauerborn, J., Müller-Stöver, D., and Hershenhorn, J. (2007). The role of biological control in managing parasitic weeds. Crop Protection, 26(3), 246–254. https://doi.org/10.1016/j.cropro.2005.12.012

Zeid, S. M., and Komeil, A. A. (2019). Impact of intercropping of different crops with two faba bean cultivars on infestation with broomrape (*Orobanche crenata* Forsk.). Egyptian Journal of Agronomy, 41(3), 283-295. https://doi.org/10.21608/agro.2019.16518.1182

تأثير التحميل المنفصل لكل من نباتات الحلبة والكتان، على فترات زراعة مختلفة، على معدل إصابة الفول العريض (*Vicia faba*) بحشيشة الهالوك (*Orobanche crenata* Forskali)

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الملخص العربي

أُجريت تجربتان متتاليتان في أصص زراعية خلال موسمي النمو الشتوي 2022-2023 و2023-2024 في المعمل المركزي للزراعة العضوية (CLOA) التابع لمركز البحوث الزراعية (ARC) في الجيزة، مصر. هدفت الدراسة إلى تقييم الكفاءة الزراعية-البيئية لأنظمة مختلفة للزراعة البينية (المحاصيل المصاحبة). وقد شملت الدراسة صنفاً من الفول البلدي مقاوماً (جيزة 843) وآخر حساساً (نوبارية 1)، وتم تحميل كل من الصنفين بصورة منفصلة بمحصولين مصاحبين يعملان كمحاصيل جاذبة (مصيدة) وهما الحلبة *Trigonella foenum-graecum* والكتان *Linum usitatissimum*، وذلك باستخدام مواعيد زراعة متتالية لكل منهما على انفراد، بهدف تحسين مكافحة الهالوك وتعظيم مكونات محصول الفول البلدى. صُممت التجربة وفق نظام القطع المنشقة مرتين (split-split-plot) ضمن تصميم عشوائي كامل (CRD) وبثلاث مكررات. وتم قياس الصفات الزراعية، ومكونات المحصول، ومؤشرات نمو الهالوك (الشماريخ الزهرية فوق سطح التربة والدرنات تحت سطح التربة) عند مرحلة النضج الفسيولوجي. وأظهر التحليل الإحصائي المشترك اتساقاً عالياً في النتائج عبر كلا الموسمين؛ حيث تفوق الصنف المقاوم "جيزة 843" بشكل معنوي ومستمر على الصنف "نوبارية 1" في جميع الصفات الاقتصادية الرئيسية (عدد القرون، ووزن القرون، ومحصول البذور). وفي المقابل، كان التأثير المستقل للمحاصيل المصاحبة محدوداً، حيث تفوقت الحلبة معنوياً على الكتان فقط في عدد القرون. وأظهر التفاعل الثلاثي عالي المعنوية أن الجمع بين الصنف "جيزة 843" والحلبة في المعاملة الرابعة (T4) قد حقق أفضل النتائج فيما يتعلق بمؤشرات المحصول والنمو الخضري. ومن الناحية الزمنية، نجحت ايضا المعاملة (T4) بفعالية في تثبيط نمو وتطور طفيل الهالوك *Orobanche crenata* إذ سجلت أقل عدد من الشماريخ الظاهرة (2,50) وأقل كتلة حيوية لها (6,80 جم)، مما أدى إلى حصر الطفيل عند مرحلة الدرنة تحت الأرضية (6,08 درنة/أصيص) ومنع الإزهار وتكوين البذور.

الكلمات الدالة : الفول البلدى (اصناف) ، تحميل المحاصيل ، محاصيل صائدة ، ، الحلبة *Trigonella foenum-graecum* ، الكتان *Linum usitatissimum* .